The Effects of CNTs Types on The Structural and Electrical Properties of CNTs/PMMA Nanocomposite Films

J. Al-Osaimi[1], N. Alhosiny[1,2,*], Ali Badawi[1] and S. Abdallah[1]
[1]Department of Physics, Faculty of Science, Taif University
[2]Department of Physics, Faculty of Science, Aljouf University
* Corresponding author: E-mail address: nalhosiny@yahoo.co.uk (Dr. Najm Al-Hosiny) ; TelFax: +96646262799

Abstract**-- The structural and electrical properties of carbon nanotubes (CNTs) of different types (SWCNT, DWCNT and MWCNT) / poly-methyl methacrylate (PMMA) composites films have been investigated. The composite were prepared in the form of films by the solution casting technique. Their structural properties were investigated by X-ray diffraction (XRD). XRD revealed that CNTs are well immersed in the polymer chains. The dc electrical conductivity measurements of CNTs/PMMA films show that there is one order of magnitude enhancement relative to plain PMMA film.**

Index Term**— CNTs/PMMA composite, dc electrical properties ,structural properties**

I. INTRODUCTION

Throughout the last decade, science made great strides towards studding carbon nanotubes (CNTs) since its discovery by Sumio Ijima in 1991[1]. CNTs have many advantageous properties such as , extremely high strength, lightweight, elasticity, high thermal and air stability, and high electrical and thermal conductivity [2]. Such properties make it possible to utilize CNTs in different technological applications such as nanoelectronic, superconductors, photovoltaic devices [3], electromechanical actuators, electrochemical capacitors, and nanocomposite materials [4-12].Different methods have been used to produce CNTs such as arc discharge, laser ablation and chemical vapour deposition (CVD)[13]. Recently, huge intention has been given to the use of CNTs in conjugated polymer to harness their exceptional properties [2]. Therefore, CNTs/polymer nanocomposites are a new class of promising materials for potential applications, such as photovoltaic cells, transport layers and light emitting diodes (LED's) . We selected the Poly(methyl methacrylate) (PMMA) as matrix polymer for this study due to its validity for a wide variety of production and processing techniques and its amorphous character (thereby avoiding potential complications related to crystallization) [14].

In this work, different types (single walled- (SW), double walled- (DW) , and multi walled- (MW)) of concentration 0.5 wt% CNTs were added to PMMA to form CNTs/PMMA nanocomposite films using casting solution technique. The structural properties of the prepared composite films have been investigated using X-ray diffractometer. Also, dc electrical conductivity of the prepared CNTs/PMMA composite films was studied.

II. EXPERIMENTAL PART

A. *Preparation of CNTs/PMMA nanocomposite films*

The composite films of CNTs/PMMA of different types were prepared using casting technique. The PMMA solution were prepared by dissolving PMMA (Sigma Aldrich) in chloroform (Fluka) with ratio 1:27. The solution was stir for long time (24h). Several films of CNTs/ PMMA composite were prepared by adding the desired weight (0.5 wt%) of CNTs powder (Chengdu Organic Chemicals Co. Ltd.) to the above solution and stir for 4 hours on a magnetic stirrer. The produced mixture casted in Petri dishes and left in a ventilated fuming hood till it completely dry and solidify. Three films of PMMA + different types (SWCNT, DWCNT and MWCNT) were obtained, The dried films were reasonably homogeneous and clear.

B. Measurements:

X-ray diffraction pattern were carried out with an automated powder diffractometer (Bruker D8-advace diffractometer) with Cu X-ray tube (Wavelength: $k_{\alpha 1}$=1.540598), the tube potential is 40 KV and the tube current is 40 mA.

The dc electrical resistivity was measured in an Oxford Optistat cryostat at room temperature. An electrometer type Keithly 6517B and an Oxford temperature controller IT053 were connected to a personal computer (PC) via GPIB interface. TNT5004 card and the data was recorded on a PC.

III. RESULTS AND DISCUSIONS

A. Structural Properties (X-ray diffraction measurement)

Fig. 1 shows X-ray diffraction pattern of our composite films for different CNTs types. It is easily seen that there are three dominant peaks at 2θ =26.6°, 43.45° , 54.7° and 78.2°, which correspond to the hexagonal graphite structures (002), (101), (004), and (110).respectively. Although the intensity of the DWCNTs at the main peak is somehow larger than the MWCNTs, it is clearly seen that the intensity obtained from MWCNTs is higher than that obtained from DWCNTs and SWCNTs. This is due to the increase in the number of inner shells of CNTs.

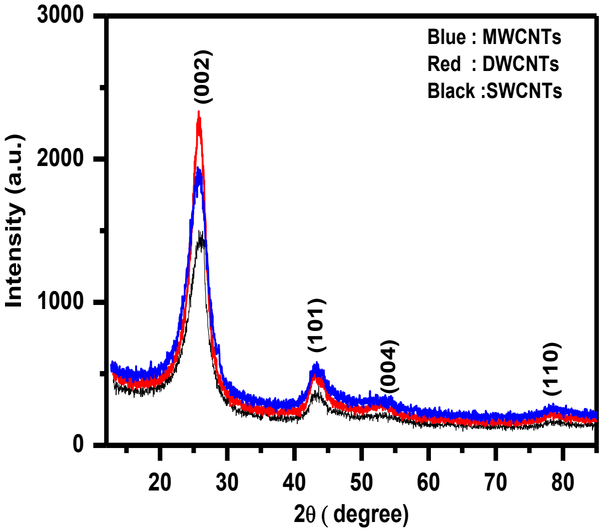

Fig. 1. X-ray diffraction pattern of different types of CNTs.

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Fig. 2 shows the X-ray diffraction patterns for different types of CNTs/PMMA composite films. It can be observed that CNTs/PMMA composite film show low intensity broad band peaks similar to the pure PMMA with the MWCNTs having the highest intensity. This behavior may indicate that there is no covalent interactions between CNTs and PMMA [15]. In Addition, it proves a homogeneous dispersion of CNTs in PMMA matrix. Similar results were obtained by Won-Chun Oh et al [16]. In their work, they concluded the absence of CNTs peaks in x ray diffraction pattern in CNT/TiO_2 composite for photo-degradation activity.

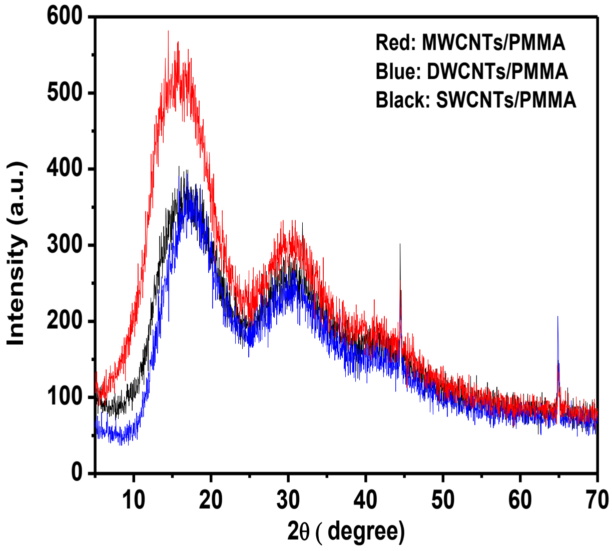

Fig. 2. X-ray diffraction patterns of different types of CNTs/PMMA composites.

To clarify the change, we plot the results for each type of powder CNTs and CNTs/PMMA composite films as shown in Fig.3 (a, b, and c). it is clearly observed that powder CNTs exhibits diffraction peaks at 2θ=26.6°, 43.45°, and 54.7° which are correspond to (002) , (101), and (004) phases, while other broad bands diffraction peaks at 2θ= 17° and 32 are correspond to PMMA, which indicates its amorphous nature [17].

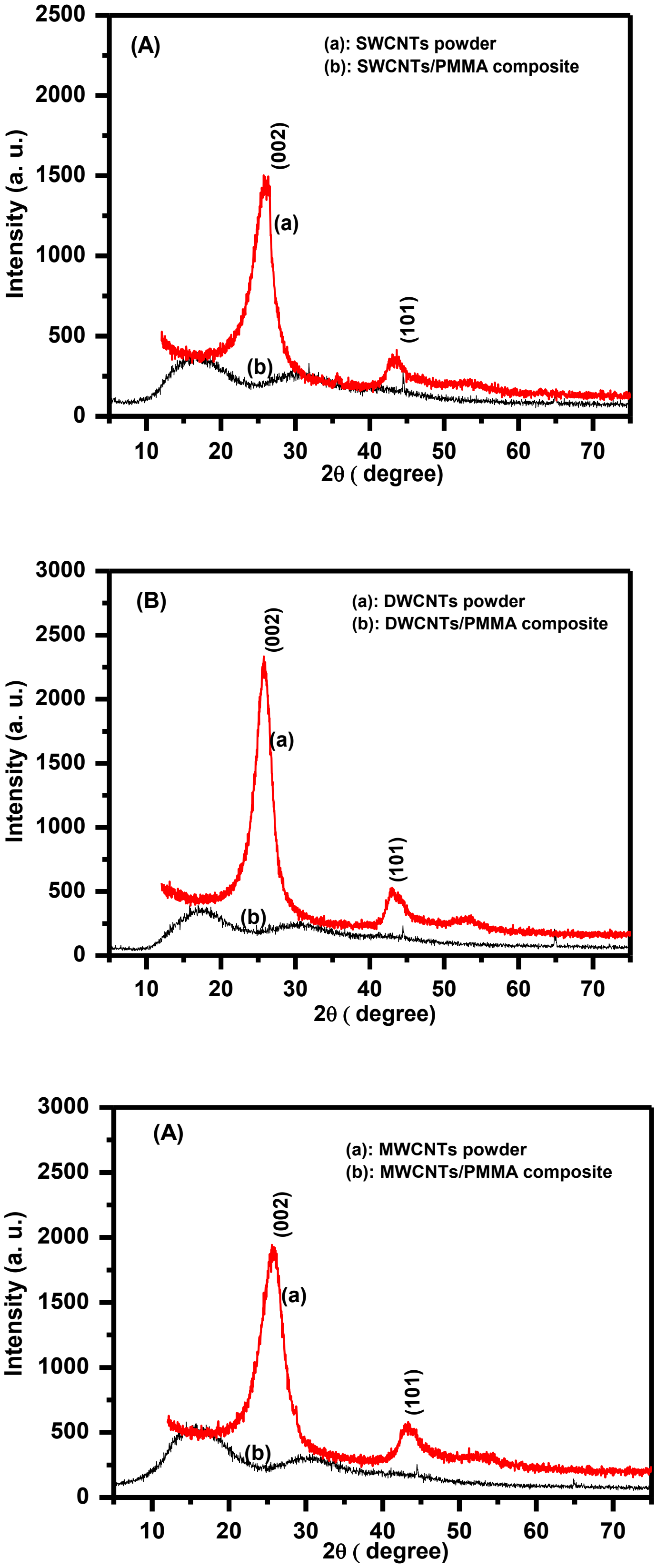

Fig. 3. X-ray diffraction patterns of: (A) SWCNTs powder and SWCNTs/PMMA composite, (B): DWCNTs powder and DWCNTs/PMMA composite, and (C): MWCNTs powder and MWCNTs/PMMA composite.

B. Electrical properties measurements

Fig. 4 shows the dc electrical conductivity (σ) of the CNTs/PMMA composite films for different CNTs types at room temperature. The results show that the value of σ for PMMA was about 1.3×10^{-10} ($S.m^{-1}$) and the value of σ for SWCNTs/ PMMA film was about 9.5×10^{-10} ($S.m^{-1}$). The increase in the dc electrical conductivity of SWCNTs/PMMA composite films can be explained as follows: the existence of SWCNTs as a filler in PMMA matrix help to create extensive conductive networks that facilitate electrons transport in the composite. In other words, CNTs cause the current to flow even through without direct contacts between CNTs. This mechanism is called 'quantum mechanical tunneling' effect [18], where electrons can move through the insulator between conductive elements (SWCNTs) with a certain probability. i.e., electrons can hop from conductor to conductor by ''tunneling'' through the insulating barrier. Our results show that there is five times enhancement of electrical conductivity for SWCNTs/PMMA relative to plain PMMA. For DWCNTs/PMMA composite film, σ decrease to about 7.5×10^{-10} ($S.m^{-1}$). However, the σ increases again to reach about 8.2×10^{-10} ($S.m^{-1}$) for MWCNTs composite film. The dc conductivity has a minimum value at DWCNTs/PMMA. This point is in need for further investigation.

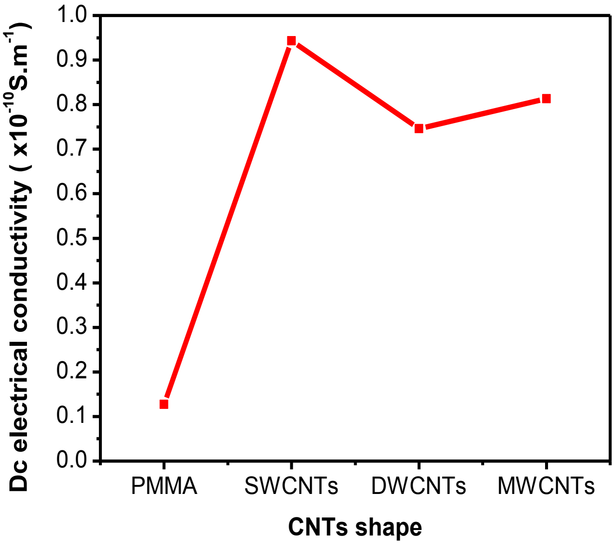

Fig. 4. DC electrical conductivity for CNTs/PMMA nanocomposite films with different CNTs types and PMMA pure.

IV. CONCLUSION

Composite films of CNTs/PMMA has been fabricated with different CNTs types using casting technique. The CNTs/PMMA were characterized using dc conductivity circuit and X-ray diffractometer. We have found that the CNTs is well dispersed within the polymer chains with higher intensity for the MWCNTs due to the higher number of inner shells. The dc electrical conductivity measurements of CNTs/PMMA show that there is nearly one order of magnitude enhancement relative to plain PMMA film indicating the effect of CNTs on the electrical properties of the polymer. The DWCNTs has the lowest effect on the electrical properties of the PMMA, which suggests further investigation and may be correlation with the XRD results.

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